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EXPERIMENTAL TREATMENT OF CITRUS-CANNERY EFFLUENT IN FLORIDA*

by

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The disposition of industrial wastes has become a problem of increasing seriousness during the past few years. Much has already been accomplished in the treatment of wastes from food plants, particularly dairy, corn, pea, tomato, packing house and beet sugar wastes, but nothing has been offered regarding the proper treatment of wastes from citrus canning plants. One possible explanation for this may be that such plants are usually located in more or less sparsely inhabited area and the public health aspects of the problem were not in general considered of commanding importance. However, with the steady growth of the citrus products industry, along with the fact those regions in which citrus canneries are located have become a winter playground (especially in Florida), the necessity of a better method of waste disposal, particularly for some plants, has become apparent.

In Florida, the problem of proper disposal of waste waters from citrus canneries has been recognized by the canners themselves and they have undertaken constructive work to remedy the situation. The researches reported in this paper were made possible by the financial cooperation of the Florida Canners' Association, and with the engineering advice of the Florida State Board of Health.

At the present time, waste waters from citrus canneries in Florida are disposed of by:

A. Emptying into Lakes: As shown later in this paper this method may cause pollution and destruction of fish life. This danger is particularly present when the body of water is of insufficient area to properly dilute the waste.

B. Handling by City Sewerage System: In some instances this has caused damage to pumps and piping, clogging of sand beds and excessive foaming in Imhoff or primary settling tanks. Most cities in Florida are reluctant to handle such wastes.

C. Primary Settling Tanks: This method has not proven satisfactory because retention time is too short and the material shows little tendency to flocculate and settle. The addition of chemicals to encourage flocculation has not yielded effluents of greater purity. Even when the wastes are filtered clear (a practice that would be economically impossible) no significant improvement is shown in the 5-day biological oxygen demand (B.O.D.), or oxygen consumed value.

D. Flooding of Waste Lands: To use this method, an isolated section of land of sufficient area and with a low water table of favorable porosity is necessary. Intermittent application followed by discing is required to prevent ponding. When ponding occurs without preventative measures, conditions become favorable for mosquito and fly breeding. Some canneries using this method of disposition have obtained satisfactory results. Unfortunately, all canneries are not located so that this method can be used.

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E. Disposing in Tide-water Rivers: This practice is, of course, limited to those canneries located on the coast. The few canneries so located have not as yet experienced any difficulties, although the danger of polluting shell fish must be kept in mind.

Nature and Quality of Liquid Wastes

These factors will vary according to the size of the cannery and whether the plant is packing sections, juice or both. From Table 1 it may be seen that plants packing sections alone have stronger effluents than those merely packing juice. The quantity of waste water will also vary from approximately 30,000 to 40,000 gallons per 10-hour day to as much as nearly half a million gallons per 10-hour day. A survey was made of one large cannery packing 4,000 cases of No. 2's per 10-hour day and having an effluent discharge of 226,000 gallons per day of 10 hours. This is, therefore, at the rate of 56.5 gallons per case of No. 2's. From conversations with other canners this is just about what might be expected as an average for citrus canneries; some believed that it ran about 50 gallons per case.

The waste waters from the particular cannery studied may be roughly grouped into seven different kinds:

1. Can-cooler overflow.
2. Fruit-washing waste water.
3. Peeling-table waste water.
4. Sectionizing-table waste water.
5. Exhaust-box overflow.
6. Flushing water from floors, etc.
7. Waste alkali from peeling tanks*.

Difficulty in sampling made it impossible to keep separate all seven groups. It should be pointed out, too, that the values given are not absolute and should be used for comparative purposes only.

1 and 2. Can-Cooling Tanks and Fruit-Washing Waste Waters. The overflow from the cooling tanks is used to wash the incoming fruit and part of this combined waste water is pumped to the peeling tables for flushing purposes. The combined waste waters from cooling tanks and fruit washer amounted to about 2200 gallons per hour with an oxygen consumed value of 45 parts per million (p.p.m), a 5-day B.O.D. of 20 p.p.m. and a pH of 7.2.

3. Peeling Tables. The plant had 64 peelers. It was not possible to measure the volume of waste waters from these tables, but as stated above the water used here is part of that from the cooling tanks and fruit washer. The waste waters from the peeling tables showed an oxygen consumed value of 560 p.p.m., a pH of 7.2 and a 5-day B.O.D. of 380 p.p.m.

4. Sectionizing Tables. The plant had 230 sectionizers. The waste water from the tables had an oxygen consumed value of 2840 p.p.m., a pH of 4.5 and a 5-day B.O.D. of 2480 p.p.m. The combined volume of waste waters from the peeling and sectionizing tables amounted to about 15,800 gallons per hour.

* This type of waste would be met with only in plants sectionizing fruit. Alkali tanks are generally dumped 2 or 3 times a week depending upon the extent of pack. In some instances, the material is emptied into cess pools.

5. Exhaust Box Overflow. This amounted to approximately 45 gallons per hour with an oxygen consumed value of 1280 p.p.m., a pH of 6.1 and a 5-day B.O.D. of 1000 p.p.m.

Daily samples* of the effluent from this plant, over a period of about 6 months, showed the oxygen consumed value to vary from a minimum of 150 p.p.m. to a maximum of 1440 p.p.m.; and 5-day B.O.D. from a minimum of 100 p.p.m. to a maximum of 1400 p.p.m.

The composition of waste waters from citrus canneries consists chiefly of inorganic salts and organic solids (organic acids, pectin and sugars). Of the total solids, from 2 to 94 percent consist of sugars (calculated as reducing sugars) and from 0.04 to 0.5 acid as citric. The nitrogen content is very low, amounting to only about 10 p.p.m.

The waste waters are usually quite unstable (the relative stability averaging approximately 30 percent) and rather quickly undergo decomposition giving rise to offensive odors. This is especially true where decomposition takes place under anaerobic conditions, the septic material having an odor not unlike that of an extremely dirty hog pen.

Upon standing, most of the suspended material in the fresh waste flocculates, but the floc does not readily settle: part rises to the surface, part remains in suspension and part will settle. When septic, the floc generally rises to the surface.

Experimental

To learn the extent of pollution of lake water by citrus cannery effluents, eight lakes in the vicinity of Winter Haven, Eagle Lake, Dundee and Haines City, Florida, were sampled once a month for 13 months. Samples were taken at approximately the center of the body of water and five feet beneath the surface. Samples for bacteriological examinations were taken just beneath the surface. Sampling was thus accomplished some distance from the outfalls of the canneries, the outfalls being located at the shore or in canals connecting many of the lakes. Sludge deposits were sometimes quite noticeable near the outfalls. In one canal receiving waste waters gassing was prevalent, especially during warm weather. Since there is no current in the canals connecting the lakes, flow of water depends upon wind direction.

Methods of analysis were those given in Standard Methods of Water Analysis of the A.P.H.A., Seventh Edition.

Space will not permit presentation of data from all the lakes sampled, but results are given for three. Some of the data for the lake at Dundee are plotted in Fig. 1. Lake Silver was taken as a control; this body of water has never received any cannery effluent. Upon this lake is located a public bathing beach. The data from the pond at Florence Villa is given because this shows what takes place after citrus cannery effluent is no longer allowed to enter a small body of water. After April, 1937, no effluent was conducted to this pond. In examining the tables it should be borne in mind that in general the lakes received citrus cannery effluent from about December to April.

* These were composites of hourly samples.

Referring to Tables II to IV, the most important factor is dissolved oxygen. If a small amount of organic matter is mixed with the water the natural oxygen content will take care of the load and no ill effects will be noted. However, if organic material is added to a point where the oxygen is depleted it will mean the destruction of aquatic life, and putrefactive action will soon give rise to a public health nuisance. It is generally conceded that while any dissolved oxygen remains, there should not be "putrefaction". It should be added, however, that practically any value below 50 percent saturation is likely to be accompanied at times by malodorous conditions. Such a condition existed for a time in the pond at Florence Villa.

The amount of dissolved oxygen in water necessary to support fish life seems to be a matter of some dispute. The quantity necessary will, of course, depend upon the species of fish, some being able to survive in much lower concentrations of oxygen than others. It was noticed in some of the lakes sampled that when the oxygen content was low the fish would jump. It is probably safe to say that the dissolved oxygen in a game fish stream or lake should not for any length of time during the day be lower than 4 p.p.m. and that the average for 24 hours should always be over 6 p.p.m. In some instances in the lakes sampled the dissolved oxygen at the time of sampling was very near 6 p.p.m. and even lower. This is particularly striking in the case of the lake at Dundee (Table II). In general, the dissolved oxygen decreased during the canning season.

In some instances dissolved oxygen was at the point of supersaturation, especially during the summer. This was probably due in part to the oxygenation brought about by the chlorophyll bearing plants and organisms which were abundant in these lakes. Although the lakes have no regular surface flow of water, they are fed by underground springs and during the summer receive hugh amounts of water in surface run-off from the violent showers. The reoxygenation on the surface was probably at a minimum due to lack of turbulence and flow.

The 5-day B.O.D. values of the lakes showed less dramatic changes, although in general there seemed to be a tendency for an increase in B.O.D. during the canning season. This is clearly indicated in the lake at Dundee (Table II.). The decrease in B.O.D. will also be noticed for the pond at Florence Villa which received no cannery effluent after April, 1937.

The solid content (total, inorganic, organic and suspended) seemed to vary considerably and showed no definite trend.

The bacterial count of the lake waters showed a tendency to increase during the canning season. This factor, was, however, somewhat confused by rainfall. After heavy rains (which come during the early summer and fall) the bacterial count increased, especially in those cases where the lakes received street washings as well as cannery effluents. Escherichia coli was identified on several occasions. The absence of the coliform group in the waters of Lake Silver was noteworthy.

To summarize: analyses of lake waters receiving cannery effluent, in some cases showed positive evidence of pollution and danger to fish life. Such evidence was not, however, clear-cut in every case.

Laboratory Experiments in the Treatment of Citrus-Cannery Effluents

The studies reported here were undertaken for the purpose of developing new or improved methods of disposal which could be applied to any citrus cannery in Florida. Methods already described, and some of which have been satisfactory in particular instances, are not applicable to all citrus canneries. A few canneries have found that none of the methods described can be used in their particular case, and for this reason attention was directed toward finding a satisfactory, practical and economical method which would be applicable to all citrus canneries.

Space will not permit a complete report of all the methods tried. Discussion must be limited to a summary of the results.

Chemical Precipitation. The screened effluent was treated with lime, ferrous sulfate, alum, sodium aluminate, ferric chloride, bentonite and various combinations of these chemicals. Clear effluents could be obtained quite readily, but such effluents in general had a higher oxygen consumed value than the untreated waste. Aeration of the chemically treated effluents (accomplished by spraying into the air) did not significantly improve their quality.

Activated Sludge. A compact sludge, amounting to about one percent by volume, was obtained, but the effluent showed little improvement over that before treatment.

Contact Filter and Sand Filter. The filters clogged and gave considerable trouble. If given proper attention it is probable such filters would work, but the large space required, cost of construction and supervision while in operation seemed to discourage their use on a large scale.

Trickling Filter. Such favorable results were obtained in the laboratory using this method of purification that it was decided to construct a small pilot plant at one of the canneries.

Pilot Plant--Trickling Filter

The experimental trickling filter was designed by Mr. George Catlett, Chief of the Division of Engineering of the Florida State Board of Health. The filter is shown in Figure 2.

The filter consisted of a concrete shell 8 feet deep, resting on suitable underpinnings to permit ready drainage and free air circulation. As constructed, the area of the filter amounted to 1/867 of an acre. Previous laboratory experiments indicated that Ocala limestone would not be satisfactory as ballast because of extensive erosion. So-called Florida flint rock was obtained, this stone having approximately the following composition:

Silica (SiO_2)	93.1%
Calcium Carbonate	0.76
Magnesium Carbonate	0.31
Iron and Aluminum (Fe_2O_3 and Al_2O_3)	2.86

The stone ranged in size from about one inch to three inches; the larger pieces being packed at the bottom of the filter. The stones held up well during the experiments, although there was some erosion.

Referring to Fig. 2, at the left of the filter is a tower upon which is mounted the dosing tank having a capacity of 8.86 gallons. This tank, of concrete and coated internally with an asphalt paint, was provided with a bell and siphon arrangement so that dosing would be automatic. Orifices of suitable size were placed in the pipe leading to the dosing tank and the pipe from the dosing tank to the distributor on the filter. By regulating the size of these orifices, the time of dosing and resting of the filter could be accurately controlled.

The distributor consisted of two pipes with perforations of suitable size so that the entire bed would be uniformly dosed. It was made to rotate (by means of a motor) at about 12 R.P.M. The distribution arm was raised above the bed so that there would be some splashing of the material as it gushed from the arms (Fig. 3).

The biological film on the ballast was built-up by adding dry skim milk powder and cow dung. Later, orange and grapefruit juices were sprinkled on the bed. In this manner a fairly satisfactory formation was obtained in 2 or 3 weeks.

The filter was in operation approximately 10 hours a day with the exception of Saturdays and Sundays.

After the filter had been in operation for about 60 days, the cannery closed for about a month. This rest-period had no serious effect in that the efficiency of the filter built up rapidly when it was started again.

Hourly samples were taken of the filter influent and effluent and of the settling-tank effluent. Hourly temperature readings were also made of the influent and effluent of the filter. Hourly morning samples were composited for analysis; hourly afternoon samples were also composited thus giving the functioning of the filter in the morning as compared with the afternoon. Samples were kept on ice until ready for analysis; in no case was analysis made more than five hours after the samples were taken.

Effluent from the filter was allowed to flow into a settling tank (Fig.4) where it was retained for about two hours. This permitted some settling of the material sloughing from the filter, and that naturally present in the waste. Settling was not, however, entirely complete and the effluent from the settling tank always contained finely suspended matter. Longer retention time would not remedy this, because all the settleable material was found to settle within two hours.

It was necessary to frequently clean the sludge from the settling tank, since this sludge became septic (especially during warm weather) gassed, created foul odors and floated on the top of the tank where it was discharged with the effluent.

An analysis of the sludge is given in Table V. If dried, the sludge would have a value as a fertilizer, and is comparable in composition to sludge obtained from domestic sewage.

In practice, it would be necessary to oil the surface of the settling tank to control mosquitoes.

Operation of Filter and Discussion of Results. Before being pumped to the filter, the canning plant effluent was passed through a 40 mesh screen with openings of approximately 0.015 inches (Fig. 5).

A summary of the data for three dosing rate equivalents is given in Table VI. During the periods indicated, the filter was dosed for about three minutes and rested three minutes. Although reductions in 5-day B.O.D. were not as great as some authorities might expect, it is quite likely that the lakes would be able to take care of an effluent having a 5-day B.O.D. of about 100 p.p.m. Such an effluent would be obtained with a dosing rate of slightly more than 1.5 million gallons per acre per day, if the canning plant effluent had a 5-day B.O.D. of about 900 p.p.m. It was found that a rate of 1.5 million gallons per acre per day gave the best results. At rates greater than this, the efficiency of the filter was impaired.

Reaction of the Influent and Effluent. Normally the pH of the influent to the filter was about 6.3, while the effluent had a pH of approximately 7.3. The effluent from the settling tank also had a pH of nearly the same as the filter effluent. If, however, the settling tank became septic, its effluent became more acid than that of the filter.

Temperature of Influent and Effluent. The filter influent always had a higher temperature than the effluent, the difference between the two amounting to 20°F. or more. The comparative coolness of the effluent was, of course, due to evaporation.

It was found the cooler the atmospheric temperature, the less efficient the purification. This is probably due in the inability of the organisms on the ballast to grow and function as efficiently at low temperatures as at higher temperatures (Fig. 6).

Effect of Rest Period upon Efficiency of Filter. The filter was normally in operation about 10 hours a day and rested overnight, Saturday afternoons and Sundays. From 101 daily observations, it was found that greater purification was obtained in the afternoons 50.4 percent of the time; greater purification in the mornings 39.6 percent of the time, while 10 percent of the time showed equal purification in the afternoon and morning. It should also be mentioned that there was no consistent difference between the strength of the canning plant effluent in the morning and afternoon. The data would indicate that resting overnight and week-ends probably resulted in some drying of the film with a resulting decrease in efficiency. From a practical standpoint, however, this decrease would be of relatively little importance.

Relation between B.O.D. and Oxygen Consumed Value. In the citrus cannery effluents studies, there was no consistant relationship between the oxygen consumed value and 5-day B.O.D.

Effect of Adding Nitrogenous Nutrients to Filter Influent. Since the nitrogen content of the influent was low (10 p.p.m.) it was thought that the efficiency of the filter could be increased by the addition of nitrogenous nutrients. Ten parts per million of nitrogen were added as ammonium hydroxide, ammonium carbonate, ammonium nitrate and dried blood albumen*. The results are summarized in Table VII. From the date it will be seen that the addition of blood albumen increased the efficiency of the filter. However, material cost to obtain this increased efficiency would amount to about $11.00 per 100,000 gallons of cannery effluent.

Effect of Chlorination. It was found that the chlorine demand of the particular effluent being studied ranged from 250 to 400 p.p.m. Obviously, it would be economically impossible to satisfy this demand. Experiments were, however, conducted to learn what effect partial satisfaction of the demand would have on the subsequent purification of the waste. The canning plant effluent was dosed with 50 p.p.m., the chlorinated waste then being passed through the trickling filter. It should be pointed out that the addition of even 50 p.p.m. would prove a costly undertaking in practice.

Partial satisfaction may have an effect upon ultimate purification as shown in Table VIII, but the degree of purification attained would not warrant the additional expense.

The data obtained from recirculating citrus cannery effluent are given in Table IX. Each experiment represents data obtained when the filter had reached equilibrium. This was taken to be when the oxygen consumed value and 5-day B.O.D. of the filter effluent were constant, or nearly so. Recirculation at the rate indicated, and under the conditions of the experiment, failed to have an effect upon ultimate purification of citrus cannery effluent.

Size of Trickling-Filter Needed. Our experiments indicated that citrus cannery effluents could be satisfactorily treated by means of a properly operated trickling filter of adequate size. From a practical standpoint, the size of such a filter becomes of primary importance. The size will depend upon the quantity of effluent to be treated, and the B.O.D. of this material. These factors will vary with nearly every citrus cannery. Although it is not possible to accurately define the size of filter needed in every instance, a very close approximation may be obtained from the formula:

$$\frac{\dfrac{\text{pounds of effluent to be treated}}{1,000,000}\ (\text{B.O.D. to be removed})}{0.246}$$

In the above formula 0.246 is a constant obtained by multiplying the depth of the filter (6 feet) by the average pounds of B.O.D. removed per cubic foot of filter. From the data obtained in our experimental work, and which extended over a period of seven months, the average pounds of B.O.D. removed per cubic foot of filter was found to be 0.041. This figure represents the value for reasonable or normal operation.

As an example of the use of the above formula, suppose a plant is packing 4000 cases of No. 2's per 10-hour day.** Such a plant would have an effluent

* This should not be confused with dried, whole blood which contains considerable insoluble matter. The blood albumen used was dried haemoglobin (with, of course, a small amount of plasma) and contains little insoluble matter when fresh. Briefly, it is prepared by centrifuging citrated whole beef blood, thus separating the plasma from the haemoglobin. The haemoglobin is then spray-dried.

**This would be an average size plant.

of about 226,000 gallons, or 1,882,580 pounds per 10-hour day. In the case of 24 hours' operation (and this fact must be taken into consideration) there would be 542,400 gallons, or 4,518,192 pounds. Again, assume this effluent to have a maximum B.O.D. of 800 p.p.m., and that this will be reduced to 100 p.p.m. by the treatment. Substituting these values:

$$\frac{\frac{4,518,192}{1,000,000}(700)}{0.246} = 12,855 \text{ sq. ft. surface area.}$$

It should be pointed out that the size of the filter must be calculated as though the canning plant were running 24 hours a day.

Cost of Disposal Plant. This question cannot, of course, be definitely answered. In Florida, the cost would be high because of the high price of flint rock used for ballast. This material costs about $3.50 a cubic yard delivered. At this price ballast for packing the filter cited above would amount to about $10,000. To this figure must be added construction cost.

A cheaper material might be found in the form of broken tile, concrete pipes or cypress blocks of small size. Lime rock could be obtained cheaply, but it would have to be replaced each season. Ballast material costing not more than $1.00 per cubic yard delivered would have to be used.

The contention that the price of ballast is high may be ridiculed by some sanitary engineers. It must be remembered, however, that when the citrus canner invests in a disposal plant, the only way he can get his money back is from the consumer, i.e. by increasing the price of the canned product. The consumer might very well rebel at this.

Summary

It was found that the effluents from citrus canneries amounted to about 56 gallons per case of No. 2's and had a 5-day B.O.D. varying from 100 to 2000 p.p.m. Effluents from plants processing juice had a lower B.O.D. than those processing sections, or juice and sections. The chemical composition of the effluents consisted chiefly of inorganic salts and organic solids (organic acids, pectin and sugar). Of the total solids, from 2 to 94 percent consisted of sugars, and from 0.04 to 0.5 percent acid as citric. The nitrogen content was very low, amounting to only about 10 p.p.m.

Some lakes of insufficient area for proper dilution and into which citrus cannery effluents were emptied, showed positive evidence of pollution and danger to fish life.

Purfication of effluents was attempted by chemical precipitation, activated sludge, contact filter, sand filter and a trickling filter.

Trickling filtration, using an experimental unit, was found the most satisfactory and from the data obtained it was found:

Trickling filtration offered the most promising solution for the disposition of citrus-cannery effluents in those cases where flooding of isolated tracts of land or emptying into tidewater rivers or large bodies of water is impractical.

Addition to the cannery effluent of nitrogenous nutrients in the form of blood albumen resulted in an increase in filter efficiency of the filter, but material cost of such practice would be too high.

Chlorination of the cannery effluent was too expensive. Partial satisfaction of the chlorine demand slightly increased the efficiency of the filter, but cost would be excessive.

Under the conditions of the experiments, recirculation had no effect upon the efficiency of the filter.

The higher the mean air temperature the greater the efficiency of the filter.

Construction costs of a trickling filter in Florida would be high if Florida flint rock were used as set forth in these experiments.

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Table I. -- Analyses of Screened Cannery Effluents

	Plant #1	Plant #2	Plant #3	Plant #4
Type of Pack	Sections & juice	Sections	Juice	Sections
Total Solids	1403	4084	672	3550
Organic Solids	1189	3633	551	3246
Inorganic Solids	214	451	121	304
Suspended Solids	61	248	171	287
pH	7.2	6.1	6.5	5.6
5-Day B.O.D.	583	2000	343	1722

Table II -- Condition of Water in Lake at Dundee

Approximate Area = 19.6 Acres
Approximate Volume Water = 77,000,000 Gallons

	April 1937	May 1937	June 1937	July 1937	Aug. 1937	Sept. 1937	Oct. 1937	Nov. 1937	Dec. 1937	Jan. 1938	Feb. 1938	Mar. 1938	Apr. 1938
Temp.Water, °F.	81	....	....	86	86	....	72	66	68	66	70	84	79
Total Solids, P.P.M.	294	....	....	189	201	....	160	162	207	183	200	250	218
Organic Solids P.P.M.	192	....	....	85	121	....	120	70	182	92	105	160	113
Inorganic Sol. P.P.M.	102	....	....	104	80	....	40	92	25	91	95	90	105
Suspended Sol. P.P.M.	2	....	....	15	20	....	19	13	6	8	14	13	18
pH	6.88	....	....	7.38	7.90	....	7.65	7.81	7.10	6.10	6.10	7.40	6.93
Dissolved Oxy. P.P.M.	1.3	....	....	2.4	8.2	....	14.2	11.4	7.2	3.0	1.3	1.3	7.0
5-Day B.O.D. P.P.M.	11.6	....	....	2.8	2.0	....	3.3	2.7	3.3	9.2	10	10	2.8
Bacteria per cc													
20°C.	1100	....	....	24	183	....	210	560	4150	34800	2000	27900	7400
37°C.	1100	....	....	14	82	....	215	830	3470	17900	2500	33000	6000
Coliform Group	40	....	....	0	<1	....	0	4	1000	100	230	100	100
Tot.Rainfall, in.	4.87	3.76	6.80	8.44	4.27	3.50	5.55	5.07	1.16	0.94	0.37	4.48	0.09

Table III -- Condition of Water in Lake Silver (Control)

Approximate Area = 52 Acres
Approximate Volume of Water = 204,000,000 Gallons

	April 1937	May 1937	June 1937	July 1937	Aug. 1937	Sept. 1937	Oct. 1937	Nov. 1937	Dec. 1937	Jan. 1938	Feb. 1938	Mar. 1938	Apr. 1938
Temp.Water, °F.	....	....	....	88	86	82	74	66	66	64	65	78	75
Tot.Sol., P.P.M.	138	....	....	134	146	129	104	109	125	143	103	113	127
Org.Sol., P.P.M.	80	....	....	50	83	95	59	43	40	126	33	43	49
Inorg.Sol.P.P.M.	58	....	....	84	63	34	45	66	85	17	70	70	78
Sus.Sol., P.P.M.	1.5	....	....	1.8	6.2	3	3	2	1	0.4	0.6	0.3	0.3
pH	5.88	....	....	7.40	5.88	7.38	6.58	7.10	6.50	5.84	6.80	6.80	6.58
Dis.Oxy., P.P.M.	8.3	....	....	8.4	7.4	8.3	10.0	11.0	9.8	8.7	8.9	9.4	8.0
5-Day B.OD, P.P.M.	0.33	....	....	2.4	0.5	1.1	0.4	1.0	0.5	1.0	0.8	2.1	0.0
Bacteria per cc													
20°C.	200	....	....	56	33	100	275	142	60	351	200	250	360
37°C.	0	....	....	17	117	190	234	160	52	194	137	250	230
Coliform Group	0	....	....	0	0	0	0	0	0	<1	0	0	0
Tot.Rainfall, in.	4.87	3.76	6.80	8.44	4.27	3.50	5.55	5.07	1.16	0.94	0.87	4.48	0.09

Table IV -- Condition of Water in Pond at Florence Villa*
Approximate Area = 3 Acres
Approximate Volume Water = 11,700,000 Gallons

	April 1937	May 1937	June 1937	July 1937	Aug. 1937	Sept. 1937	Oct. 1937	Nov. 1937	Dec. 1937	Jan. 1938	Feb. 1938	Mar. 1938	Apr. 1938
Temp.Water, °F	83	....	....	86	86	82	72	68	68	63	63	80	77
Tot.Solids, PPM	352	....	....	305	355	372	308	330	340	345	310	364	414
Organic Solids P.P.M.	340	....	....	127	266	157	85	189	221	97	56	88	114
Inorganic Sol. P.P.M.	12	....	....	178	89	215	223	141	109	248	254	276	300
Suspended Sol. P.P.M.	8	....	....	3	12	3	2	3	1	3	0.4	2	6
pH	7.00	....	....	7.17	7.48	7.27	6.07	5.40	6.59	7.20	6.60	6.20	6.74
Dissolved Oxy. P.P.M.	0	....	....	1.6	1.8	5.6	4.3	11.9	9.3	9.3	8.5	8.7	8.1
5-Day B.O.D. P.P.M.	220	....	....	13.2	3.1	1.5	1.3	....	0	1.6	1.2	2.7	0.9
Bacteria per cc													
20°C.	320000	....	....	3600	119	75	166	280	216	230	175	90	200
37°C.	140000	....	....	19400	148	240	184	410	190	120	110	370	170
Coliform Group	670	....	....	1	0	0	<1	<1	<1	<1	0	<1	0
Tot.Rainfall, in.	4.87	3.76	6.80	8.44	4.27	3.50	5.55	5.07	1.16	0.94	0.87	4.48	0.09

*No canning plant effluent went into this pond after April 1937.

Table V -- Analysis of Sludge from Settling Tank in Treatment of Citrus Cannery Effluent

Fresh Sludge

Sp. Gr. at 20°C./20°C.	1.001
Water	99.89%
Organic Matter	0.06
Inorganic Matter	0.05

Dry Sludge

Crude Fat (ether extract)	7.42%
Total Nitrogen, as Ammonia	4.90
Ash	31.90
Phosphates (P_2O_5)	2.37

Table VI -- Summary of Data for Trickling Filter. Dosing, Intermittent

Operating Period	12/5 to 1/9	1/18 to 3/7	4/10 to 4/25
Equiv. Dosing Rate, M.G.P.A.P.D.	2.16	1.38	1.56
Mean Air Temp. °F.	63.6°	68.9°	68.6°
Temp. Infl., °F.	84.3°	87.4°	89.8°
Temp. Effl., °F.	64.2°	65.5°	70.1°
Oxygen-Consumed Value (p.p.m.)			
Infl.	762	755	1021
Effl.	309	113	184
Settling Tank	279	99	131
5-Day B.O.D. (p.p.m.)			
Infl.	641	633	876
Effl.	302	68	108
Settling Tank	291	79	101
pH Value			
Infl.	6.49	6.25	6.48
Effl.	7.04	7.33	7.42
Settling Tank	7.02	7.27	7.33
Overall Reduction in Oxygen-Consumed Value, %	63.4	86.8	87.1
Overall Reduction in 5-Day B.O.D., %	54.6	87.5	88.4

Table VII -- Effect of Adding Nitrogenous Nutrients to Citrus Cannery Effluent and its Ultimate Purification by Trickling Filtration
(Dosing rate, 2,160,000 Gallons per acre per day)
(10 p.p.m. of nitrogen added)

Nutrient	5-Day B.O.D.		Lbs. B.O.D. Removed per 100 cu.ft. of Filter per Day
	Influent, PPM	Settling Tank, PPM	
Control	760	140	4.24
Inorganic Ammonium Salts	771	174	4.13
Blood Albumen	934	165	5.36

Table VIII - Effect of Partially Satisfying the Chlorine Demand of Citrus-Cannery Effluent and Subsequent Treatment with a Trickling Filter
(Dosing Rate: 2,160,000 Gallons per acre per day)
(50 p.p.m. chlorine added)

	5-Day B.O.D.		Lbs. B.O.D. Removed per 100 Cu. Ft. of Filter per Day
	Influent, P.P.M.	Settling Tank, P.P.M.	
Control	760	140	4.24
50 P.P.M. Chlorine	822	133	4.67

Table IX -- Effect of Recirculation on Purification of Citrus-Cannery Effluent Filter Dosed Intermittently
(Rate of feed plant effluent: 1,560,000 gallons per acre per day)

5-Day B.O.D. Plant Effluent P.P.M.	5-Day B.O.D. Settling-Tank Effluent, P.P.M.	Lbs. B.O.D. Removed per 100 Cu. Ft. of Filter per Day	
876	101	3.84	Control, no recirculation.
704	10	3.44	Filter influent consisted of one part plant effluent plus one part of filter effluent

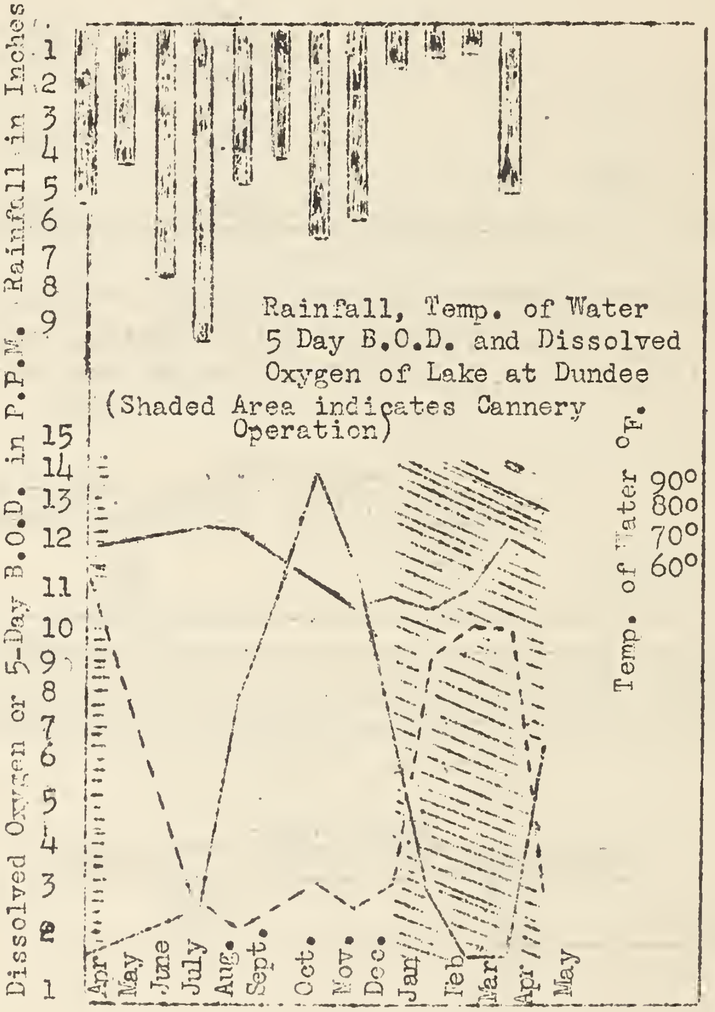

Figure 1

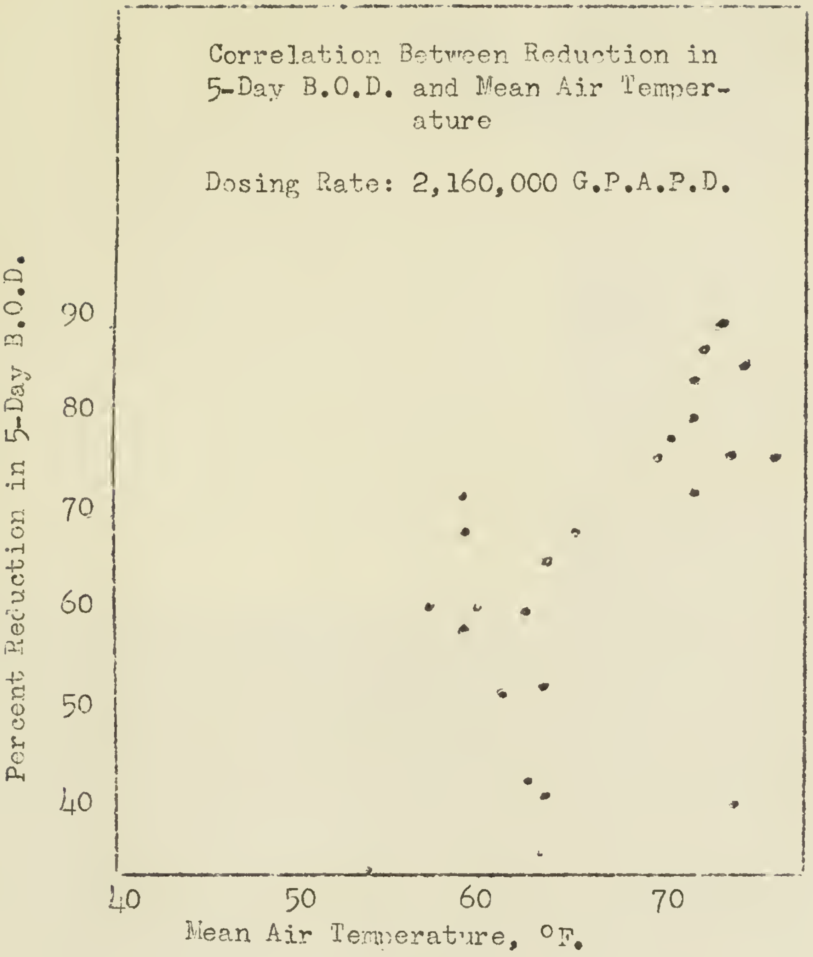
Correlation Between Reduction in 5-Day B.O.D. and Mean Air Temperature
Dosing Rate: 2,160,000 G.P.A.P.D.
Percent Reduction in 5-Day B.O.D.
90
80
70
60
50
40
40
50
60
70
Mean Air Temperature, °F.

Figure 6.

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